

# Database Access and Problem Solving in the Basic Sciences

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## ABSTRACT

*This study examined the potential contribution that access to a database of biomedical information may offer in support of problem-solving exercises when personal knowledge is inadequate. Thirty-six medical students were assessed over four occasions and three domains in the basic sciences: bacteriology, pharmacology, and toxicology. Each assessment consisted of a two-pass protocol in which students were first assessed for their personal knowledge of a domain with a short-answer problem set. Then, for a sample of problems they had missed, they were asked to use a database, INQUIRER, to respond to questions which they had been unable to address with their personal knowledge. Results indicate that for a domain in which the database is well-integrated in course activities, useful retrieval of information which augmented personal knowledge increased over three assessment occasions, even continuing to increase several months after course exposure and experience with the database. For all domains, even at assessments prior to course exposure, students were able to moderately extend their ability to solve problems through access to the INQUIRER database.*

## OBJECTIVE

Databases constitute one form of the computerized information resources that support educational needs of medical trainees. Available databases range from bibliographic resources such as MEDLINE [1-3] to fact-and-text databases that provide information specific to basic biomedical domains [4-6]. Our objective was to develop and implement a structured environment to investigate how information from a database may augment the personal knowledge of medical students in problem-solving exercises. In this paper, we report results for one research cohort of medical students in their first and second year of medical school on four assessments conducted over a period of thirteen months.

## BACKGROUND

This work draws on research on problem solving in medical education and practice, the nature of problem solving as investigated in cognitive psychology, and how "gaps" in knowledge may be supported by information resources.

Problem solving is a central focus in both the practice of medicine and the educational activities that develop skills in clinical reasoning [7]. Problem solving in medicine requires physicians to apply knowledge in diagnosis and management to the care of patients. Domain knowledge plays a central role in problem solving in medicine [8]. Medical students and physicians draw upon knowledge represented both in personal memory and obtained from external information resources. As students learn the profession and physicians practice medicine, there is a continual interplay of the knowledge held in personal memory with the information represented in external resources [9,10].

This study was motivated, above all, by the conjunction of two trends. As the volume of biomedical knowledge continues to grow [11,12], the potential to improve education and health care through access to this information is expanding. As databases and other information resources proliferate, the access to these resources increases as well. This research explores the value of structured biomedical database information for problem solving in situations where personal knowledge is known to be insufficient.

## RESEARCH QUESTION

Our work examined one primary research question. For problem solving, do personal knowledge and the ability to augment one's knowledge through database access evolve in similar ways over time and across biomedical domains?

## METHODS

### Overview

This study assessed one cohort of medical students on four occasions for: (1) their ability to solve problems based on their personal knowledge only, and (2) their ability to solve, with assistance from a computerized database, parts of these problems for which personal knowledge was inadequate [13]. The study was carried out in three biomedical domains: bacteriology, pharmacology, and toxicology.

### Subjects

The subjects were a sample of randomly selected medical students from the first-year class of the University of North Carolina (UNC) entering in the fall of 1990 invited to participate in the research. Students with a graduate degree or an undergraduate degree in any of the three study domains were excluded from the sample. Thirty-six students completed all four assessments over thirteen months.

### INQUIRER Database

INQUIRER is a database resource currently serving three basic science domains [4-6]. Microbiology is a first-year course in which students routinely use the database, INQUIRER, which is fully integrated in the bacteriology component of the course, to solve faculty-generated problem scenarios. Pharmacology is a second-year course in which INQUIRER supports three segments: general principles, antimicrobials, and autonomic/somatic drugs. Pharmacology INQUIRER was first used in the 1991-92 academic year and in this initial application may be considered partially integrated in the course activities. For this study, toxicology INQUIRER is a control database in which students are likely to have little or no personal knowledge since toxicology is not taught during the curricular period of this research. The INQUIRER toxicology database was developed using portions of the "Hazardous Substances Data Bank" from the National Library of Medicine. In bacteriology and

pharmacology, the INQUIRER database is available to the entire medical school class. Toxicology INQUIRER is available only to students participating in special research activities. As used in this research, INQUIRER ran on a VAX minicomputer and was available to students throughout the medical center.

In this study, files in INQUIRER that dealt with the specific entities in each domain (e.g., 65 bacteria in microbiology, 105 drugs in pharmacology, and 58 toxins in toxicology) were used. Students use INQUIRER either by browsing information in a record (e.g., a specific bacterium or drug) or by constructing Boolean search queries (e.g., a retrieval of all bacteria in the database that are gram stain positive and have a morphology of rods). Across domains only the content of INQUIRER differed. The user interface and the logic for user interaction with the database were identical. Students were given a user manual and were trained in a 40-minute orientation session prior to the first assessment.

### Study Design

**Assessment Occasions:** The assessments occurred on four occasions: (1) midway through the first curricular year before the bacteriology segment in the microbiology course; (2) three months later after bacteriology instruction; (3) early in the second curricular year before the pharmacology course; and (4) three months later, after the pharmacology course segments covered in INQUIRER. Each assessment period examined two domains. The first assessment consisted of bacteriology (and a paper exercise in toxicology since the computerized database for this discipline was under development). The second assessment was made up of bacteriology and toxicology, the third of pharmacology and bacteriology, and the fourth of pharmacology and toxicology. Figure 1 outlines the sequence and content of the four assessments.

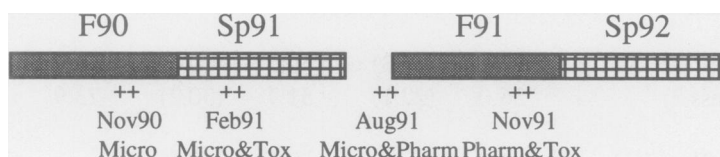


Figure 1: Assessment Occasions

**Two-Pass Protocol:** Within each assessment occasion, each domain was investigated with a "two-pass" protocol. In the first pass, domain knowledge was assessed with a written exercise consisting of six clinical scenarios, each with three to six associated questions. The questions called for short answer responses. Thirty-five minutes were allocated to the written exercise which was initially scored during the assessment session. A sample of "missed" questions (one from each clinical scenario) was then identified for the individual student to attempt to answer again, this time with access to INQUIRER. The sample of missed questions was selected using an algorithm designed to minimize the selection of trivial searches that required students only to "look up" information whose location in the database would be obvious. During the second pass through the assessment, the students were given 45 minutes to complete all six questions with database searches.

The proportion of assessment questions answered correctly on the first pass through the written exercise generated a "personal knowledge" score as one dependent measure. The database searching exercise yielded a "database-assisted" score as the second dependent measure. This database-assisted score was the proportion of correct responses for each student on this second pass through a subset of questions the student was not able to answer with personal knowledge alone.

## RESULTS

The evolution in personal knowledge (Pass 1) and the database-assisted (Pass 2) scores for the students in all

three domains across four assessment occasions is presented in Table 1. In this study, the results in personal knowledge scores and database-assisted scores cannot be considered directly comparable, although the general trends are noteworthy.

Statistical analysis of the results for the three domains indicated a main effect for assessment occasion,  $F(8,28) = 69.17$  ( $p < .0001$ ). For bacteriology, univariate analyses revealed a significant parabolic trend in personal knowledge scores (Pass 1) over the three assessments. Univariate analyses also revealed a significant linear trend in the bacteriology database-assisted (Pass 2) scores, with a rise from the first assessment to the second, and a further rise from the second to the third assessment. For pharmacology and toxicology, univariate analyses did not reveal any significant trends in personal knowledge or database-assisted scores.

## DISCUSSION

The parabolic trend in personal domain knowledge scores in bacteriology could be anticipated. There was a rise in personal knowledge scores from the first assessment prior to bacteriology to the assessment immediately following the microbiology course segment in bacteriology. Personal knowledge scores obtained five months later in a more distal post assessment decreased substantially from the personal knowledge scores immediately after the bacteriology segment. (See Table 1.)

**Table 1. Performance on Clinical Scenarios in Three Domains on Four Occasions: With Personal Knowledge and with Database Assistance (N=36)**

	Mean % Correct by Assessment Occasion							
	November 1990		February 1991		August 1991		November 1991	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
<b>Bacteriology</b>								
Personal knowledge (Pass 1)	13.0	(8.3)	50.2	(10.6)	24.2	(11.5)		
Database-assisted (Pass 2)	36.0	(22.1)	51.7	(30.2)	73.9	(22.8)		
<b>Toxicology</b>								
Personal knowledge (Pass 1)			9.5	(7.1)			8.7	(6.2)
Database-assisted (Pass 2)			33.2	(30.0)			41.7	(18.3)
<b>Pharmacology</b>								
Personal knowledge (Pass 1)					9.6	(5.4)	11.0	(6.5)
Database-assisted (Pass 2)					54.1	(17.7)	53.5	(27.1)

The database-assisted scores in bacteriology rose steadily across the three assessments. During the period between the second and third assessments, students did not have access to INQUIRER. The algorithm that guided the assignment of questions missed with personal knowledge to the database access portion of the assessment was one means of ensuring that these results are not the result of variable search tasks across students.

In contrast to bacteriology, personal knowledge scores and database-assisted scores in toxicology and pharmacology remain generally unchanged over time. The lack of significant differences seen in the toxicology personal knowledge and database-assisted scores across occasions are in accord with expectations. Since students did not have curricular exposure to toxicology during the research period, it could be expected that their personal knowledge scores would be low, with no change from the second to the fourth assessment occasions. The database-assisted toxicology scores also do not change significantly between assessment occasions.

In pharmacology, the personal knowledge and database-assisted scores appear to follow the same general trend as scores in toxicology. In this case, the fourth assessment (i.e., the second pharmacology assessment) took place after in-course coverage of the relevant topics but, due to scheduling constraints, two months before the in-course examination on these segments. Because medical students' study time tends to be allocated to examination requirements, they may not have mastered the relevant content comparable to that demonstrated in the bacteriology post-course assessment. Further, the relatively new implementation of INQUIRER in the pharmacology course resulted in an integration that was less robust than that in the bacteriology component of the microbiology course.

For all three domains, we observe database-assisted scores ranging from 33.2 to 54.1 for the initial assessment conducted in the domain. This suggests that, without any formal instruction in a domain and when personal knowledge is low, students are able to address a significant fraction of clinical problems aided by their retrievals from INQUIRER.

In this study, the evolution of personal knowledge is parabolic for a domain (e.g., bacteriology) in which the content was relatively well mastered in the course and the research assessment after instruction closely followed the in-course examination. In domains

(e.g., toxicology, pharmacology) where there is no curricular or examination pressure for medical students to master the material, personal knowledge scores appear generally flat and do not change.

In contrast, the evolution of the ability to retrieve information through database access that augments personal knowledge with information useful in problem solving begins with a moderate level of performance at the initial assessment in all domains and increases significantly in later assessments for one of the three domains (e.g., bacteriology). The trend of the database-assisted scores appears to be modulated by the extent of database integration in the course or curriculum and the degree of previous content mastery. To further examine the linear trend of the database-assisted scores in bacteriology, one hypothesis undergoing further investigation is that students may be able to recognize useful information in a database although they are not able to recall it for expression on a short-answer assessment.

The questions that were assigned for search in INQUIRER were a subset of the total set of questions for which a subject had inadequate personal knowledge suggesting that even with low domain knowledge access to a database is of value. This value may be greater for a domain that has been previously mastered. The Boolean search capability in INQUIRER is a potent feature that may distinguish it from databases used in studies that have shown no significant difference or reduced efficiency in the use of an electronic information resource over similar content presented in print [14,15]. Our future work will probe the comparison between Boolean access to structured database content and hypertext exploration of the same information.

## CONCLUSION

Our results suggest that, even in a domain in which an individual has little or no personal knowledge, the ability to retrieve relevant information from a database exists. Potentially the most striking finding of our research to date is the stable or increasing ability of students, aided by a database well integrated in the course experience, to respond to problems, even when their ability to recall personal knowledge in a domain fades. It appears that the net effect of providing an information resource to students on a continuing basis is that they may be able to maintain their ability to solve problems. They appear to be able to compensate for decreases in their ability to *recall* knowledge by sustaining (and even improving)

their ability to *retrieve* and to *recognize* pertinent information from an external information resource.

If these results generalize to other settings--for example the continuing education of practitioners--they would make a strong case for augmenting episodic continuing medical education programs with readily accessible information resources that address the subject areas of those programs [16]. Further work is underway to more fully document the knowledge and database access processes suggested by the results of this research.

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